Medical Science

25(110), April, 2021

Practical value of 3D modeling method of experimental wound channel during forensic examination of stab wound

Pavlo Kyshkan✉, Ivan Savka

To Cite:
Kyshkan P, Savka I. Practical value of 3D modeling method of experimental wound channel during forensic examination of stab wound. *Medical Science,* 2021, 25(110), 907-916

Author Affiliation:
Department of Forensic Medicine and Medical Law, Bukovinian State Medical University, Chernivtsi, Ukraine

✉**Corresponding author**
Department of Forensic Medicine and Medical Law, Bukovinian State Medical University, Chernivtsi, Ukraine;
Email: pavlo.kyshkan@bsmu.edu.ua

Peer-Review History
Received: 05 March 2021
Reviewed & Revised: 06/March/2021 to 06/April/2021
Accepted: 07 April 2021
Published: April 2021

Peer-review Method
External peer-review was done through double-blind method.

ABSTRACT

The study aimed at examination of the possibilities of using photogrammetry methods followed by 3D modeling of the wound channel and acute traumatic object during forensic medical examinations of stab wounds of soft tissues and parenchymal organs. The study was conducted on a series of 15 experimental and practical cases of stab wounds. Experimental wound channels were manufactured using alginate imprint mass with rubber-like effect "Hydrogum 5" ("Zhermack", Italy) and barbed tool with the one-sided sharpening of the blade. During the program investigation of 3D models of experimental wound channels, the linear dimensions of individual morphological parts of the wound channel were obtained with an accuracy of 0.001 cm, which allowed us to identify the instrument which caused the injury with a high probability. Taking into account the reliable results obtained in the experiment, this technique was used during the forensic medical examination of stab kidney wound, which allowed identifying the instrument of injury from among the provided ones by the investigating authorities for forensic examination of razor-barbed tools.

Keywords: Sharp Traumatic Object, Three-dimensional Spatial Modeling, Forensic Medicine.

1. INTRODUCTION

The work of forensic experts around the world is primarily aimed at conducting examinations in cases of violent death. A significant place in the structure of violent mortality is the damage caused by sharp objects, in particular, the stab wounds caused by robbery, domestic clashes, or premeditated murder. During the examination of acute trauma, forensic expert always raises the question of identification of the traumatic object, which caused the injury. Classical techniques cannot always provide a full objective establishment of individual identifying parameters of an acute traumatic object.

In the 21st century, modern technologies are widely used in medicine and forensic practice in particular. Scientists, medical practitioners, and forensic experts actively introduce modern computer programs and 3D technologies.

The introduction of 3D modeling into forensic medical practice began with the use of them to create three-dimensional models of crime scenes and fix the circumstances of the adventure (Ren et al., 2018; Buck 2013; Buck, 2007). Creation of volumetric models in cases of fire damage allowed increasing visualization of the carried out examination and providing a more objective answer about the direction of the shot (Leonov et al., 2016). Wide application of 3D modeling takes place in cases of examinations after road-transport accidents (Buck et al., 2007). In the study of external injuries, 3D modeling methods allow not only more accurately and objectively to investigate the morphological characteristics of injuries, but also to consult online or to give answers to additional questions of the investigation that arise during the investigation and can be postponed in time (Koller et al., 2019; Villa et al., 2017; Buck et al., 2018; Shakiryanova, 2017). Taking into account the significant advantages that become available when working with 3D models of scenes of an accident, there was a need to introduce three-dimensional spatial modeling directly during the forensic medical examination of the corpse.

The foundation for such studies is laid by the method of virtual dissection called “Virtopsy”, which is based on computer scanning of the body with a subsequent study of the resulting volume model of the whole body. In the absence of internal damage, it eliminates the need for a classic dissection (Grabherr et al., 2007). In addition to the feasibility of research 3D models of the whole body, studies of individual parts of the body and internal organs are equally important in the practice of forensic experts. The method of obtaining three-dimensional models based on photogrammetry of bone fractures, which can be used for remote fractological research (Savka et al., 2015), or spatial reconstruction of the plane of fracture of tubular bones (Bachinskiy et al., 2013) emphasized the prospects of this direction of research. Our preliminary studies have developed a method of three-dimensional spatial modeling of an acute traumatic object with stab wounds of soft tissues and parenchymal organs (Patent of Ukraine №145647, dated 28.12.2020).

Thus, great attention should be paid to the possibility of using photogrammetry and 3D modeling to identify the instrument of injury by morphological features of soft tissue lesions and wound channel caused by razor-barbed objects, which remained unclarified until now. The study aimed to conduct 3D modeling of the wound channel formed by a razor-barbed agent based on the photogrammetry method for further research of its morphological features and obtaining linear dimensions with high accuracy using the graphic editor “3ds Max”.

2. MATERIAL AND METHODS

The research was conducted at the Forensic Medicine and Medical Law Department of the Bukovinian State Medical University and the Municipal Medical Establishment “Regional Bureau of Forensic Medicine Expertise” (Chernivtsy, Ukraine) during 2019-2020. These researches were carried out in agreement with the basic bioethical principles of the Council of Europe Convention on Human Rights and Biomedicine (dated 04.04.1997), the Helsinki Declaration of the World Medical Association on the Ethical Principles of Scientific Medical Research with Human Participation (1964-2013), the Order of the Ministry of Health of Ukraine №6 “Instruction on forensic-medical examination” (dated January 17, 1995), the Order of the Ministry of Health of Ukraine №690 (dated September 23, 2009), and taking into account the methodological recommendations of the Ministry of Health of Ukraine “Procedure of exemption of biological objects from dead persons whose bodies are subject to the forensic medical examination and pathological examination for scientific purposes” (2018). The Committee on Biomedical Ethics of the Bukovinian State Medical University did not reveal any violations of moral and legal norms during these scientific researches (Protocol No4 dated 22.12.2020).

Experimental and practical parts of our research were conducted using our patented methods (Patent of Ukraine №145645, dated 28.12.2020; Patent of Ukraine №145646, dated 28.12.2020). Fifteen experimental wound channels were formed with the help of alginate imprint mass with rubber-like effect “Hydrogum 5" (produced by “Zhermack”, Italy), which quickly hardens, remains elastic after polymerization and allows to obtain prints with an extremely smooth surface. With high thixotropic properties, this alginate mass slides only when pressed during the obtaining of the print of an acute traumatic object and can the most accurately retain and reproduce the properties of the immersed knife blade used during the experiment. For the application of experimental damage, we used a razor-barbed agent, namely a knife with the one-sided sharpening of the blade, with a length of 9.42 cm, a width in place of the greatest thickening of the blade of 1.89 cm, a thickness of 0.1 cm. These dimensions of the razor-barbed tool were obtained using a caliper with an error limit of ± 0.03-0.15 cm. Each fragment of the wound channel was contrasted with a dye using a 1% alcohol solution of brilliant green. All fragments of the wound channel were opened parallel to its length and were placed on a rotary table, which, in its turn, was in a light cube to provide sufficient illumination. Then the material was photographed. Digital camera brand SONY RX 10 II was used for photographing. We put a number and a fragment of a scale line length of 1.0 cm on the subject for further calibration of the scale and controlling the size of the object under study in computer programs.

The resulting photos in JPEG format were uploaded into the computer program "Agisoft Photoscan", in which we created 3D textured models of the fragment of the wound channel. The obtained model and texture were exported in the format "OBJ". The next stage of the work was to move the received 3D models into the graphic space of the program "3ds max", where the calibration of the model scale is carried out. After this, it becomes possible to carry out reconstruction wound channel using 3D models of fragments of the wound channel in the graphics editor.

3. RESULTS & DISCUSSION

Measurement of the linear dimensions of the damage was first carried out by the classical method, namely, using a ruler, which allowed us to obtain the results presented in Table 1. It represents the depth of the wound channel, which consists of three fragments, according to the method of measuring the depth of the wound channel in the body of the corpse by assembling its separate parts, according to the immersion and passage of the blade in the body of the victim (in the skin and subcutaneous tissue with muscles, the wall of the cavity and in it, the inner organ and other anatomical formations). At different levels of immersion, the width of the wound channel and the distance between the corners from the side of the back of the blade were recorded similarly, illustrating the blade thickness and the length of individual fragments, which in turn reproduce the width of the blade of a traumatic acute object.

Table 1 Linear dimensions of damage to experimental wound channels, obtained using a ruler ($x \pm Sx$, n=15).

Parameter	MIN	MAX	M±m	SD
Depth of the 1st fragment of the wound channel	2.7	4	3.31 ± 0.09	0.34
Depth of the 2nd fragment of the wound channel	3.3	3.7	3.5 ± 0.03	0.12
Depth of the 3rd fragment of the wound channel	2.1	3.1	2.7 ± 0.08	0.3
Depth of the wound channel	9.5	9.5	9.5 ± 0	0
The width of the inlet in the middle part	0.1	0.1	0.1 ± 0	0
Width of the 2nd fragment of the wound channel in its middle part	0.1	0.1	0.1 ± 0	0
Width of the 3rd fragment of the wound channel in its middle part	0.1	0.1	0.1 ± 0	0
The length of the inlet	1.9	1.9	1.9 ± 1.18	4.6
Length of the 2nd fragment of the wound channel	1.7	1.8	1.77 ± 0.01	0.05
Length of the 3rd fragment of the wound channel	1.1	1.4	1.31 ± 0.03	0.1
The distance between the corners from the side of the back of the blade on the inlet	0.1	0.1	0.1 ± 0	0
The distance between the corners from the side of the back of the blade of the 2nd fragment of the wound channel	0.1	0.1	0.1 ± 0	0
The distance between the corners from the side of the back of the blade of the 3rd fragment of the wound channel	0.1	0.1	0.1 ± 0	0
Pt	< 0.05	< 0.05	< 0.05	< 0.05

The next stage of our work was to study and obtain the linear dimensions of damage of 3D models using the graphical editor "3ds max". In this case, this computer program allowed us to obtain already described dimensions, by an order of magnitude with higher accuracy up to 0.001 cm. The results of these measurements are presented in Table 2.

Table 2 Linear dimensions of damage to experimental wound channels, obtained with the help of a computer program for 3D modeling «3ds max» ($x \pm Sx$, n=15).

Parameter	MIN	MAX	M±m	SD
Depth of the 1st fragment of the wound channel 3D	2.671	3.958	3.27 ± 0.0883	0.342
Depth of the 2nd fragment of the wound channel 3D	3.272	3.717	3.51 ± 0.0305	0.1181
Depth of the 3rd fragment of the wound channel 3D	2.057	3.093	2.62 ± 0.0795	0.3081
Depth of wound channel 3D	9.416	9.421	9.42 ± 0.0005	0.0018
The width of the inlet in the middle part of the 3D	0.099	0.103	0.101 ± 0.0003	0.001
Width of the 2nd fragment of the wound channel in its middle part 3D	0.099	0.103	0.101 ± 0.0002	0.0008
Width of the 3rd fragment of the wound channel in its middle part 3D	0.098	0.102	0.100 ± 0.0003	0.001
The length of the input opening 3D	1.889	1.899	1.89 ± 0.0007	0.003
Length of the 2nd fragment of the wound channel 3D	1.673	1.809	1.77 ± 0.012	0.05
Length of the 3rd fragment of the wound channel 3D	1.081	1.443	1.31 ± 0.03	0.12
The distance between the corners from the side of the back of the blade on the inlet 3D	0.101	0.104	0.1022 ± 0.0002	0.0007
The distance between the corners from the side of the back of the blade of the 2nd fragment of the wound channel 3D	0.101	0.104	0.1018 ± 0.0002	0.0008
The distance between the corners from the side of the shoe of the 3rd fragment of the wound channel 3D	0.099	0.104	0.1014 ± 0.0003	0.0012
Pt	< 0.05	< 0.05	< 0.05	< 0.05

Analyzing the results of measurements presented in tables 1-2, we can establish a clear relationship between the dimensions obtained by classical methods and the dimensions obtained by the study of 3D models of the same damages. However, the dimensions obtained with the help of the computer program "3ds max" are an order of magnitude more accurate (Shakirianova et al., 2017). Investigating the depth range of the wound channel (Figure 1) obtained with the help of "3ds max", which is 9.42 ± 0.0005 cm; the absolute relative deviation index was 0.02%.

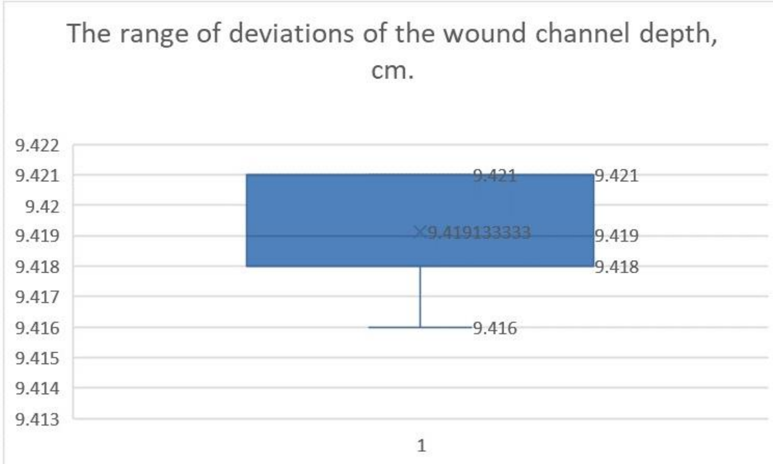

Figure 1 The range of deviations of the wound channel depth.

An important diagnostic element of the stabbed wound is the length of the inlet, which reflects the width of the blade of the knife in its widest place on the immersion of the blade in the body and allows us to draw approximate conclusions about the depth to which the penetration of the blade occurred. In the experiment, the indicator of the length of the inlet is 1.89 ± 0.0007 cm, the absolute relative deviation of which is 0.28% (Fig. 2).

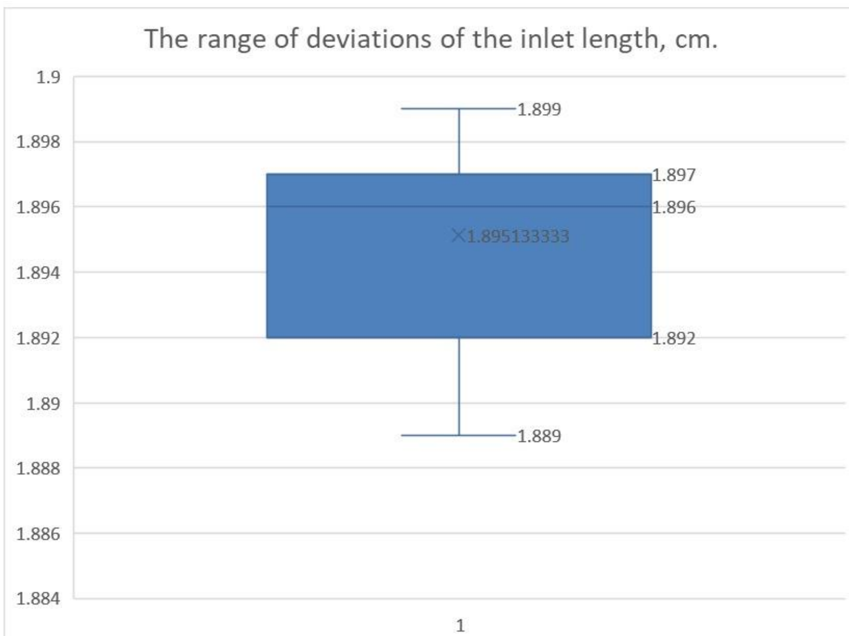

Figure 2 The range of deviations of the inlet length.

The index of the width of the inlet, illustrating the value of the blade thickness, in its middle part (Figure 3) in the experiment was 0.101 ± 0.0003 cm. The value of the absolute relative deviation for it is 1.47%. The distance between the corners from the side of the back of the blade (Fig. 4) is 0.1022 ± 0.0002 cm. The absolute relative deviation is 2.2%.

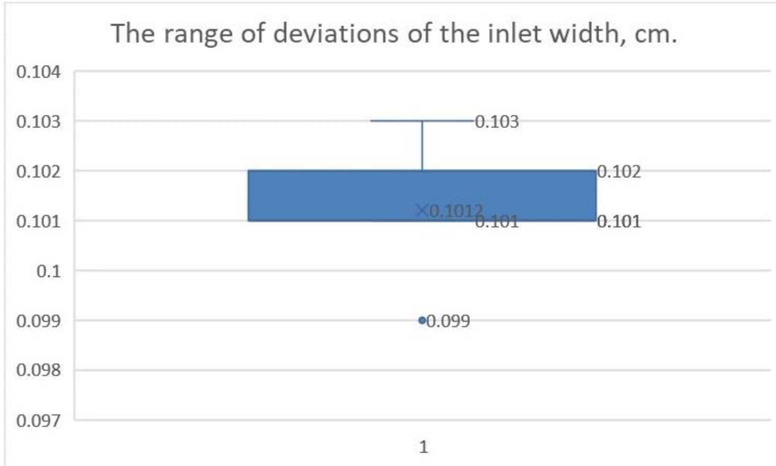

Figure 3 The range of deviations of the inlet width.

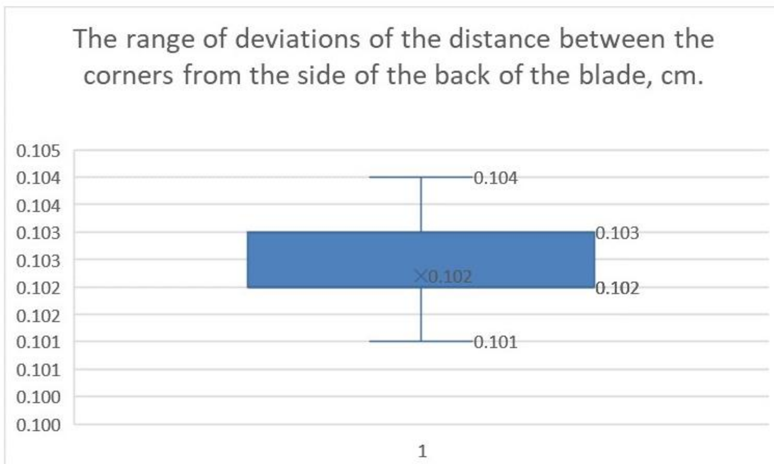

Figure 4 The range of deviations of the distance between the corners from the side of the back of the blade.

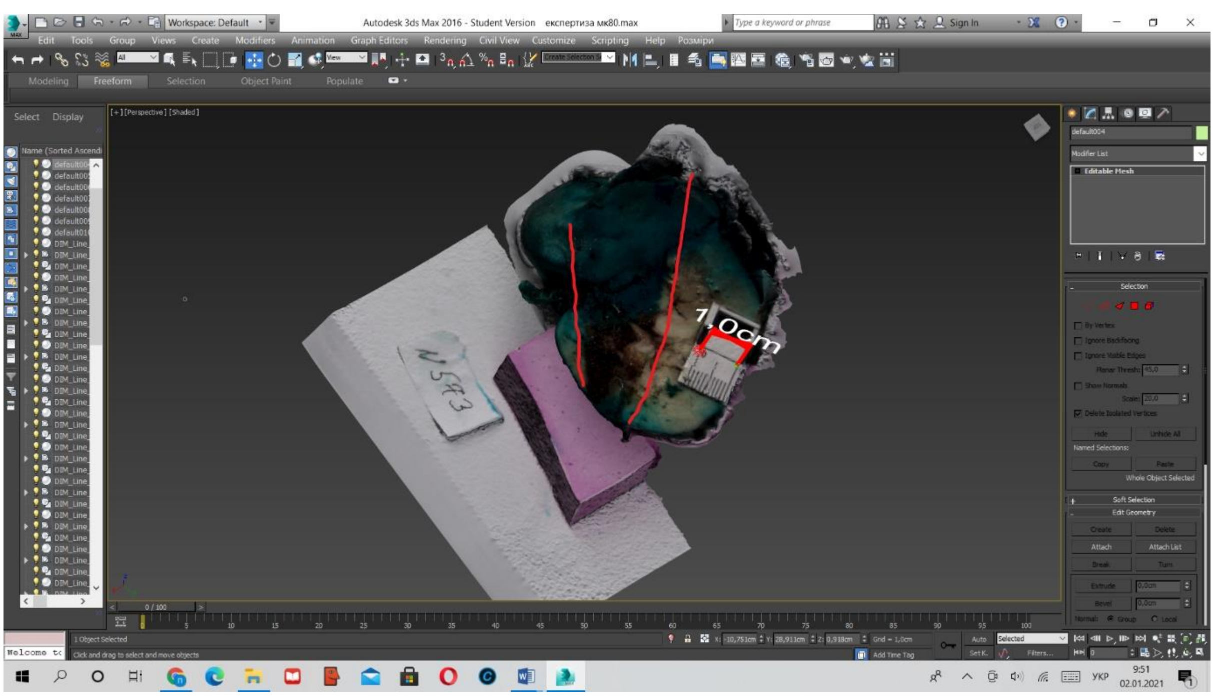

Figure 5 (3d model of the kidney sent for forensic histological examination according to expert opinion №573 from a citizen, Ms. D.) Note: contour of injury is marked by red line.

The results obtained by us in the experiment allow us to assert the high accuracy of measurements carried out with the help of a computer program for 3D modeling “3ds Max” (Minhua et al., 2010; Frishgons et al., 2018). Therefore, this technique was used in the forensic examination based on the municipal medical institution “Chernivtsi Regional Bureau of Forensic Medical Expertise”, Chernivtsi, Ukraine. For the study, by the legislation, the kidney with the existing stabbed wound (Figure 5) and probable razor-barbed instruments of injury (Figure 5) were given withdrawn in the provision of medical care (Figure 6) in the amount of 3 items.

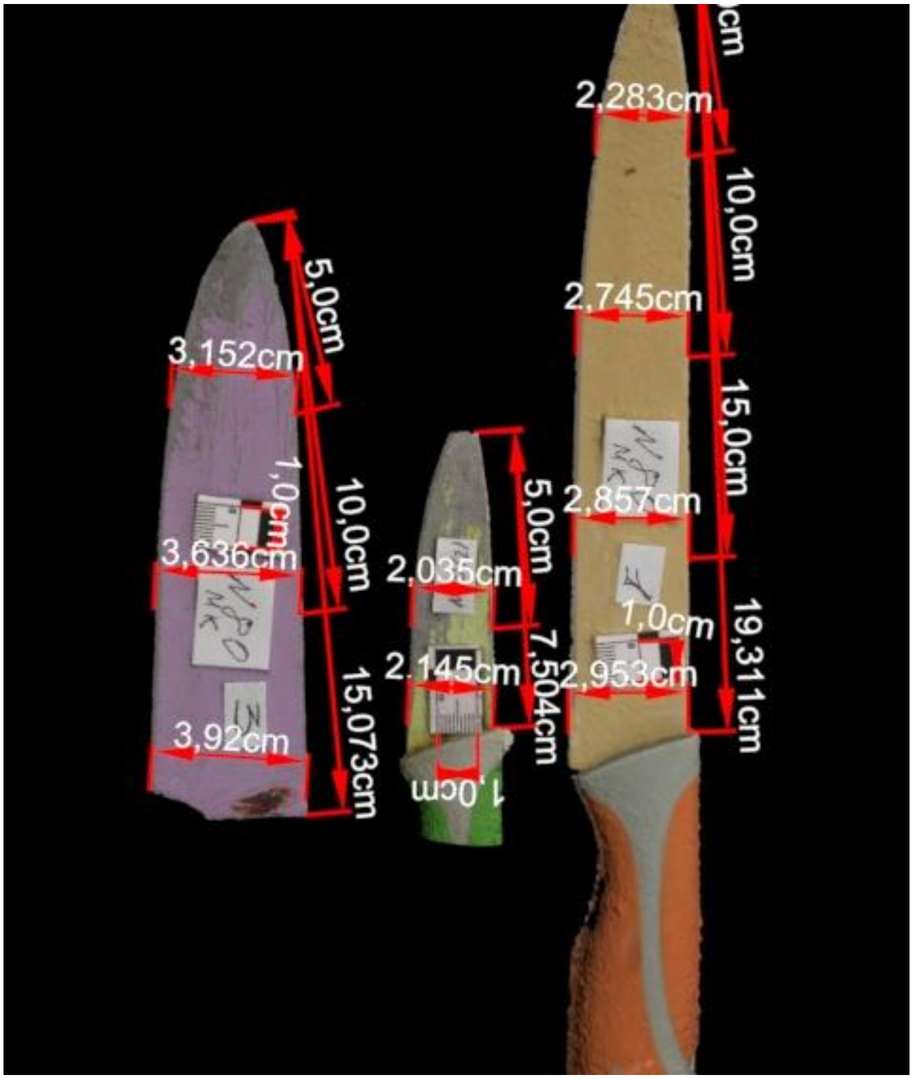

Figure 6 3d models of knives sent for forensic-criminalistics examination according to expert opinion No.80, right to left - Knife No.1 - orange; Knife No.2 -green; Knife No.3 - purple color.

After creating 3D models of all objects provided for examination and obtaining linear dimensions, they were compared in the space of the graphic editor “3ds Max” (Fig. 7-9). As it can be seen from the presented illustrations, the study of that part of the wound channel, which is formed by the knife's trouser and probable instruments of injury, the most reliable comparison occurred with knife No. 1 (Fig. 7).

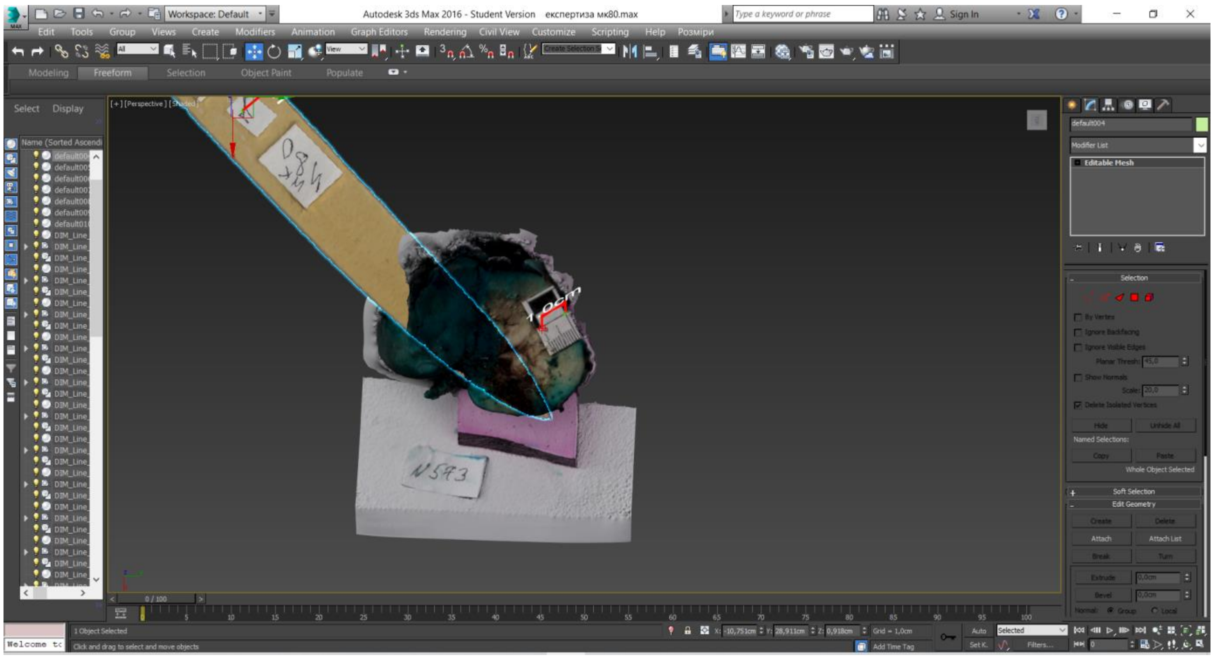

Figure 7 Identification of 3d models of kidney and Knife No.1.

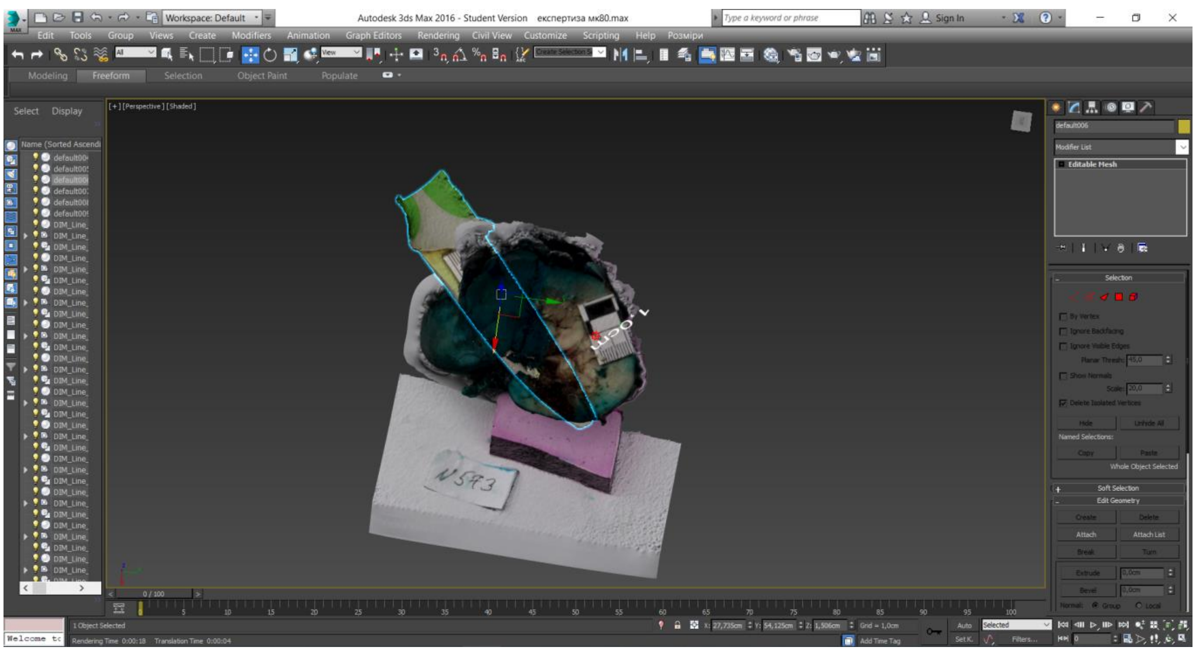

Figure 8 Identification of 3d models of kidney and Knife No.2.

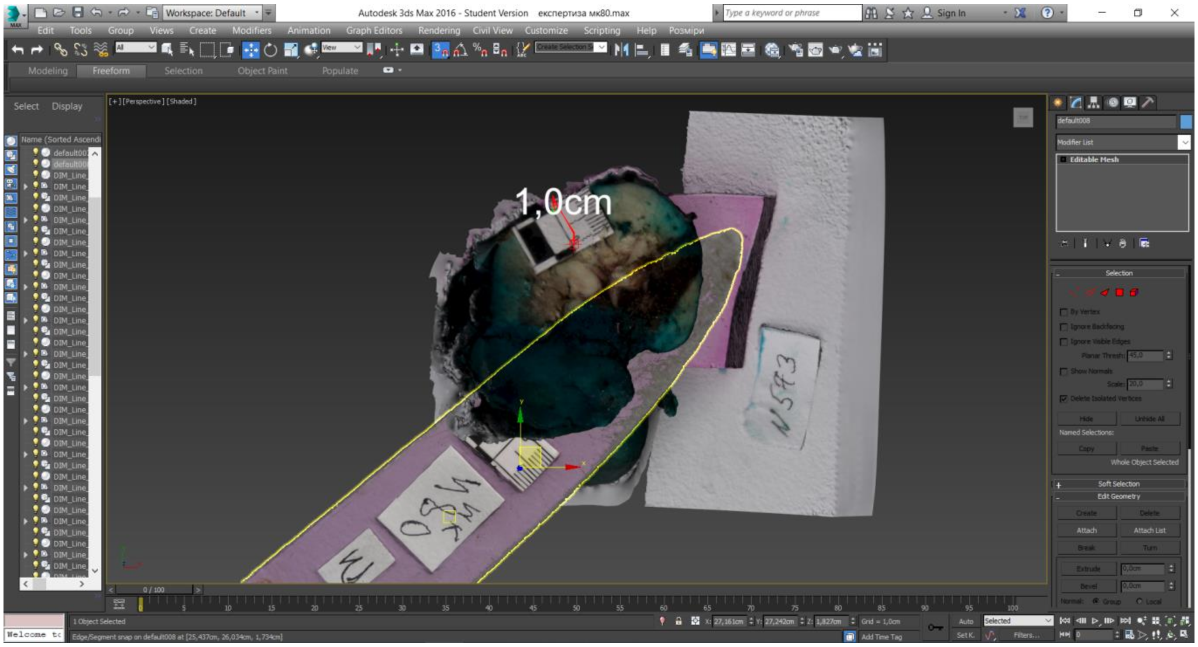

Figure 9 Carrying out identification of 3d models of kidney and Knife No.3.

In addition to the ability to obtain linear dimensions with high accuracy and to investigate the morphological characteristics of damage in 3D format, another advantage of this method is the ability to conduct a retrospective diagnosis of the most informative part of the wound channel, namely its part formed site lifting blade, i.e. handle belly. It is the knife handle belly that is the most individual part of the blade. Therefore, when combining the resulting linear dimensions of the damage and probable instruments of injury with high accuracy and the possibility of a retrospective diagnosis of the most specific part of the wound channel formed by the blade handle belly, the level of accuracy and visualization of the forensic medical examination is significantly increased.

4. CONCLUSION

The obtained results show the important diagnostic value of the study with the use of these methods as separate morphological characteristics of injuries, as well as retrospective identification of fragments of the wound channel with the instrument which caused a trauma. At the same time, forensic investigating authorities obtain a modern objective tool for selecting and identifying the used barbed and cutting tools from among the retaken others. Besides, the use of modern 3D modeling methods for forensic medical examinations allows improving accuracy and visualization, which brings the conducted examination to a new modern and higher level.

Acknowledgment

Authors would like to thank all participants of this study.

Author Contributions

All authors contributed to the research and/or preparation of the manuscript.

Funding

This study received no external funding.

Conflict of Interest

The authors declare no conflict of interests.

Ethical approval

The study was approved by the Medical Ethics Committee of the Bukovinian State Medical University" (Protocol No.4 dated 22.12.2020).

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Bachynskyi VT, Mykhailichenko BV, Savka IH. Spatial reconstruction of the fracture plane of the trubular bone, usuing modern computer technologies. Bulletin Forensic Med 2013; 2(2):6-9.
2. Buck U, Albertini N, Naether S, Thali MJ. 3D documentation of footwear impressions and tyre tracks in snow with high-resolution optical surface scanning. Forensic Sci Int 2007; 171(2-3):157-64.
3. Buck U, Bube K, Campana L, Shyma C. Validation and evaluation of measuring methods for the 3D documentation of external injuries in the field of forensic medicine. Int J Legal Med 2018; 132(2):551-61.
4. Buck U, Naether S, Braun M, Bolliger S, Friederich H, Jackowski C, Aghayev E, Christe A, Vock P, Dirnhofer R, Thali MJ. Application of 3D documentation and geometric reconstruction methods in traffic accident analysis: with high-resolution surface scanning, radiological MSCT/MRI scanning and real data based animation. Forensic Sci Int 2007; 170(1):20-8.
5. Buck U, Naether S, Rass B, Jackowski C, Thali MJ. Accident or homicide – Virtual crime scene reconstruction using 3D methods. Forensic Sci Int 2013; 225(1-3):75-84.
6. Frishons J, Kislov MA, Leonov SV. The use of 3D printing in forensic medicine. Russian J Forensic Med 2018; 4(2):10-2.
7. Grabherr S, Stephan BA, Buck U, Näther S, Christe A, Oesterhelweg L, Ross S, Dirnhofer R, Thali MJ. Virtopsy – Radiology in Forensic Medicine. Imaging Decis MRI 2007; 11(1):2-9.
8. KarjakinVYa. Forensic medical examination of injuries to piercing and cutting tools. Moscow: Medicine; 1966.
9. Koller S, Ebert LC, Martineza RM, Sieberth T. Using virtual reality for forensic examinations of injuries. Forensic Sci Int. 2019; 30:30-5.
10. KyshkanPYa, Savka IG. Three-dimensional spatial modeling of acute traumatic object in forensic medicine. Bukovinian Medical Herald 2019; 23(2):88-93.
11. KyshkanPYa, Savka IH, Kyshkan IH, inventors; Higher State Educational Institution of Ukraine "Bukovynian State Medical University", patent owner. A method of 3D-reconstruction of a wound canal formed by a prickly-cutting tool of injury. Patent of Ukraine № 145645. 2020 Dec 29.
12. KyshkanPYa, Savka IH, inventors; Higher State Educational Institution of Ukraine "Bukovynian State Medical University", patent owner. The method of establishing the correspondence of the wound canal formed by the prickly-cutting object, the tool of injury using the methods of 3D-modeling. Patent of Ukraine № 145646. 2020 Dec 29.
13. Leonov SV, Pynchuk PV. Determining the shooting location by three-dimensional modeling. Forensic Medical Expertise 2016; 3:38-9.
14. Ma M, Zheng H, Lallie H. Virtual Reality and 3D Animationin Forensic Visualization. J Forensic Sci 2010; 55(5):1227-31.
15. Ren P, Shui W, Liu J, Fan Y, Zhao W, Zhou M. A Sketch-based 3D Modeling Method for 3D Crime Scene Presentation. JDFSL 2018; 13(1):43-58.
16. Savka IH, KyshkanPYa, Kyshkan IH, inventors; Higher State Educational Institution of Ukraine "Bukovynian State Medical University", patent owner. Method of 3D-reconstruction of prickly-cutting tool of injury on wound. Patent of Ukraine № 145647. 2020 Dec 29.
17. Savka IG. Forensic substantiation of mechanogenesis and morphological signs of fractures of the low extremity long tubular bones considering their structural functional peculiarities [abstract]. Kiev; 2015.
18. Shakiryanova Yu P, Leonov SV, Pinchuk PV. Possibilities of creating three-dimensional virtual copies of objects and subsequent expert work with them. Selected Issues Forensic Medical Examination 2017; 16:93-6.
19. Shakiryanova YuP. Application of three-dimensional objects for advisory-diagnostic assistance in the “real time” mode. Bulletin Forensic Med 2017; 6(4):49-51.
20. Shakiryanova YuP. Forensic evaluation of the influence of the bevel of the blade on the morphology of stab damage [abstract]. Moscow; 2013.
21. Villa C. Forensic 3D documentation of skin injuries. Int J Legal Med 2017; 131(3):751-9.
22. Voychenko VV, V’yun VV. Using of digital technologies for lead through of situational expertis. Forensic-medical Examination 2011; 4:3-5.
23. Zagryadskaya AP. Determination of the weapon of injury in the forensic medical examination of the stab-cut weapon. Moscow: Medicine 1968.